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Baja California's Enduring Mediterranean Vegetation: Early Accounts, Human Impacts, and Conservation Status

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A unique and enduring traditional land-use system still exists in northern Baja California's Mediterranean grasslands, shrublands, oak woodlands, and conifer forests. This portion of the Californian floristic province has a pristine character rarely seen in Alta California, as the rural landscape remains little altered from the late eighteenth century, when Europeans first described it. Until recently, most of Baja California's biological environment was not as intensively exploited as Alta California's, despite the lack of effective formal protection for its wildlands. The region had experienced only a few brief gold-mining strikes. As late as 1880, agriculture essentially did not exist except around the Dominican missions. The only viable land-use was transhumance open-range cattle grazing. To this day, deliberate burning is still practiced by *vaqueros* and farmers, and wildland fires are largely uncontrolled.

To evaluate the effects of traditional land use and uncontrolled fire in northern Baja California, Minnich and Franco-Vizcaíno (1998) examined the diaries of the expeditions of Link, Crespi, Serra, Longinos-Martínez, and Arrillaga, written between 1766 and 1796. These diaries provide invaluable baseline information on the region's vegetation. Because of a mandate from the viceroy of Mexico to justify the construction of missions, the Spanish explorers were required to take daily observations of vegetation in expeditions that traversed some 1500 km throughout northern Baja California. Minnich and Franco-Vizcaíno (1998) also mapped the modern vegetation of northern Baja California using recent aerial photographs and compared it site-specifically with the Spanish accounts. They concluded that overall, the broadscale distribution, local patterning, and species composition recorded in the late-eighteenth century are still consistent with those of modern plant communities. A notable exception is the region's coastal sage scrub, significantly altered by urban and agricultural development, domestic livestock, and the spread of exotic annuals.

Based largely on the report of Minnich and Franco-Vizcaíno (1998), we summarize the extent of vegetation change in northwestern Baja California since the second half of the eighteenth century. We then review the regional history of traditional land uses, in particular grazing of domestic livestock, logging, and the lack of fire control. Additionally, we discuss the timing and impacts of the successive waves of invasions by exotic plants. In combination with grazing by domestic livestock, these have resulted in the widespread replacement by exotic annual grassland of coastal sage scrub and associated fields of native wildflowers. Finally, we provide an overview of current conservation efforts by Baja Californian governmental and nongovernmental agencies.

Climate and Physiography

Northwestern Baja California is a rugged landscape associated with 3 north–south mountain chains of the Peninsular Ranges (fig. 18.1). The Sierra Juárez comprises a discontinuous coastal chain of dissected mountains (peak elevations, 1200–1500 m) and an inland undissected tilted plateau (1600–2000 m). To the south is the Sierra San Pedro Mártir, a high mountain plateau with peaks reaching 2800–3000 m. Between these mountain chains are broad alluvial valleys and plateaus. Small coastal plains are found at Tijuana, Ensenada, and San Quintín.

The climate is Mediterranean, with winter frontal rains and summer drought (figs. 18.2 and 18.3). The mean annual precipitation ranges from 20 to 35 cm along the coast to 40 cm in the coastal Sierra Juárez, 40–50 cm in the interior Sierra Juárez, and 50–70 cm in the Sierra San Pedro Mártir (Minnich et al. 2000b). Snowfall occurs above 1600 m in the mountains. Mean winter temperatures decrease from 12–14°C in the coastal valleys to 0°C at 2200 m in the Sierra San Pedro Mártir. In summer, the North American monsoon causes afternoon thunderstorms over the inland sierras. Average summer rainfall (July–September) is locally as great as 5–10 cm along the crest of the Sierras Juárez and San Pedro Mártir, but is less than 1 cm along the Pacific coast (Minnich et al. 1993). Maximum temperatures near the coast average 20°C due to onshore flow of marine air from the upwelling Pacific Ocean, but land heating results in temperatures increasing to 30–40°C in the inland valleys and mountain uplands.

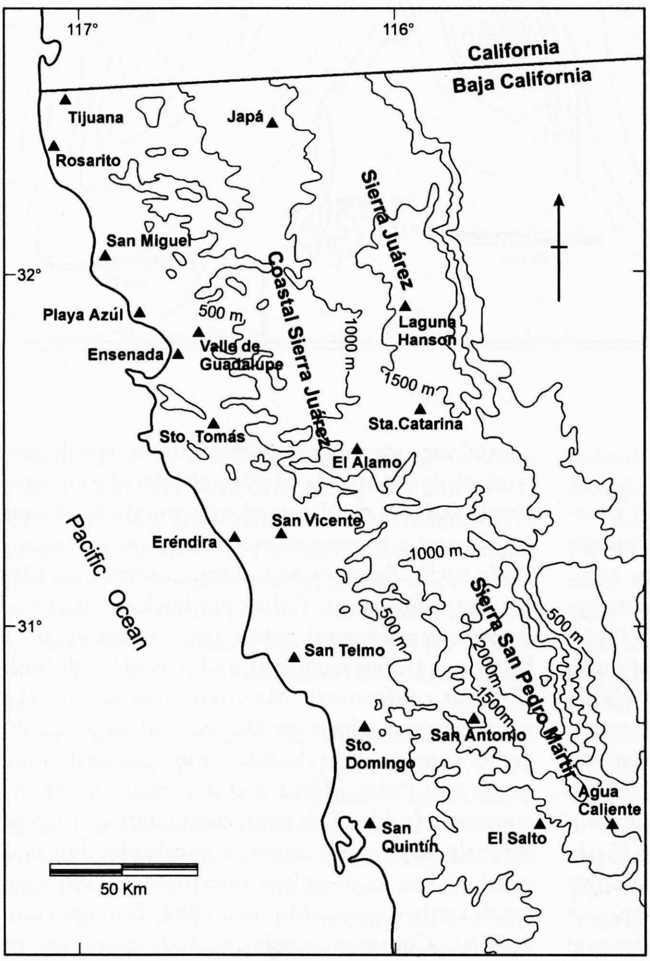

Figure 18.1. Topographic map and place names of northwestern Baja California.

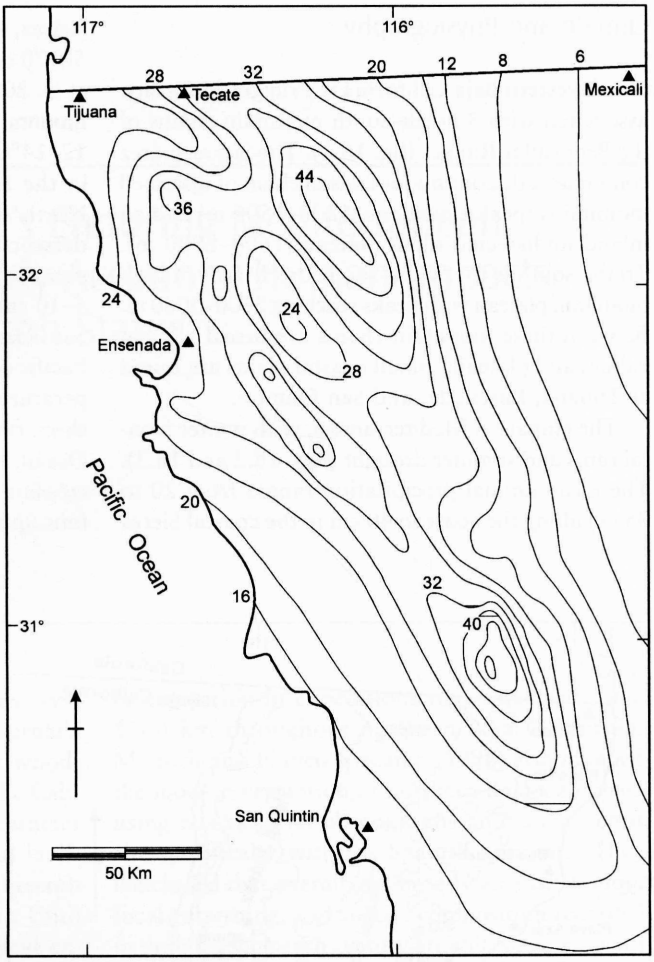

Figure 18.2. Mean annual precipitation (centimeters).

Vegetation

Plant communities show a broad altitudinal zonation similar to that in southern California (Minnich 1987; Hanes 1988; Thorne 1988; Passini et al. 1989; Peinado et al. 1994, 1995a,b). The description that follows and the vegetation map in figure 18.4 are generalized from detailed maps in Minnich and Franco-Vizcaíno (1998) and Minnich (2001). The northern coastal valleys are covered by exotic annual grasslands dominated by red brome (*Bromus rubens*), ripgut brome (*B. diandrus*), slender wild oat (*Avena barbata*), filaree (*Erodium cicutarium*), short-podded mustard (*Brassica geniculata* [= *Hirshfeldia incana*]), black mustard (*B. nigra*), and a few native herbs such as tarweed (*Hemizonia* spp).

The western foothills of the Sierras Juárez and San Pedro Mártir below 1000 m are covered by coastal sage scrub, or *matorral costero*, which consists of dense stands of drought-deciduous subshrubs 0.5–1.5 m tall mixed with woody deciduous shrubs and a few succulents. Important species include such subshrubs as California sagebrush (*Artemisia californica*), California buckwheat (*Eriogonum fasciculatum*), white sage (*Salvia apiana*), black sage (*Salvia mellifera*), and coastal brittle bush (*Encelia californica*). Maritime desertscrub, the southernmost phase of the coastal sage scrub, grows extensively in the lower foothills west of the Sierra San Pedro Mártir and northward along the coast to Eréndira. This plant community consists of a nearly continuous cover of subshrubs, but it is much richer in succulent taxa than coastal sage scrub farther north (Mooney 1988; Peinado et al. 1995b). Common species include members of coastal sage scrub as well as burbush (*Ambrosia*

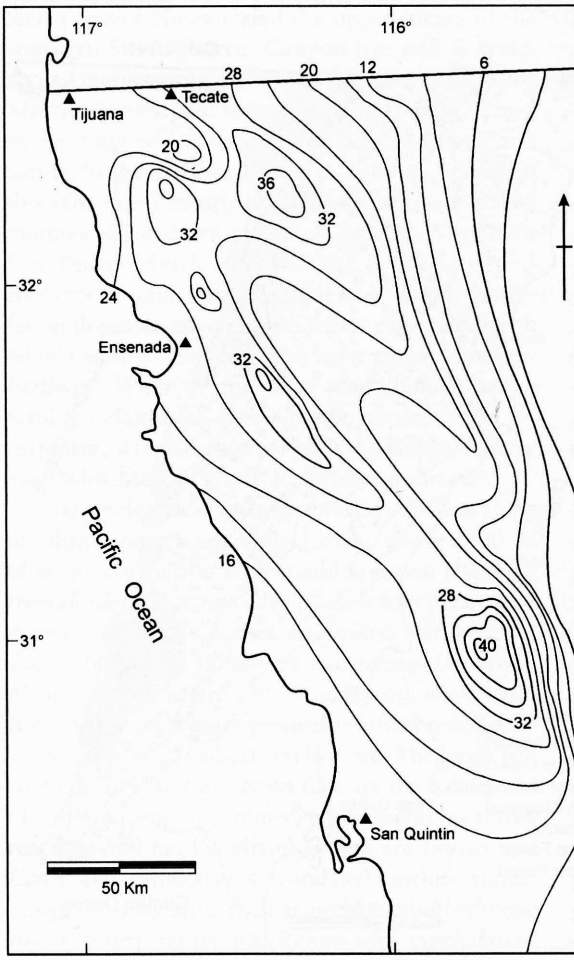

Figure 18.3. Mean winter precipitation (centimeters).

chenopodifolia), wild rose (*Rosa minutifolia*), San Diego sunflower (*Viguiera laciniata*), and desert almond (*Prunus fasciculata*). Both communities have woody deciduous shrubs of ash (*Fraxinus trifoliata*) and buckeye (*Aesculus parryi*) as well as evergreen sclerophyllous shrubs such as laurel sumac (*Malosma laurina* [= *Rhus laurina*]), lemonade berry (*Rhus integrifolia*), and jojoba (*Simmondsia chinensis*) (Peinado et al. 1995b).

Maritime desertscrub has abundant succulent taxa, including coastal agave (*Agave shawii*), velvet cactus (*Bergerocactus emoryi*), *pitaya agria* (*Stenocereus gummosus*), candelabra cactus (*Myrtillocactus cochal*), pincushion cactus (*Mammillaria dioica*), and chollas (*Cylindropuntia* spp.). Near the 30th parallel, this community grades into Sonoran desertscrub that contains the northernmost outposts of the bizarre boojum tree (*Fouquieria columnaris*) and giant cardón cactus (*Pachycereus pringlei*).

Chaparral, which consists of evergreen sclerophyllous shrubs in carpetlike stands, grows on steep slopes and in shallow, rocky soils throughout the mountains from 400–800 m near the coast to as high as 2000–2400 m in the Sierra Juárez and the Sierra San Pedro Mártir. Chamise (*Adenostoma fasciculatum*) is the widespread dominant. Mixed chaparral, which comprises a mixture of species in the wild lilac (*Ceanothus*), manzanita (*Arctostaphylos*), and oak (*Quercus*) genera, is widespread on northern exposures of the near-coast ranges and in higher elevations of the Sierra Juárez. Other important genera are mountain mahogany (*Cercocarpus*), sumac (*Malosma*, *Rhus*), *Xylococcus*, and *Ornithostaphylos*. Red-shank chamise (*Adenostoma sparsifolium*) is widespread

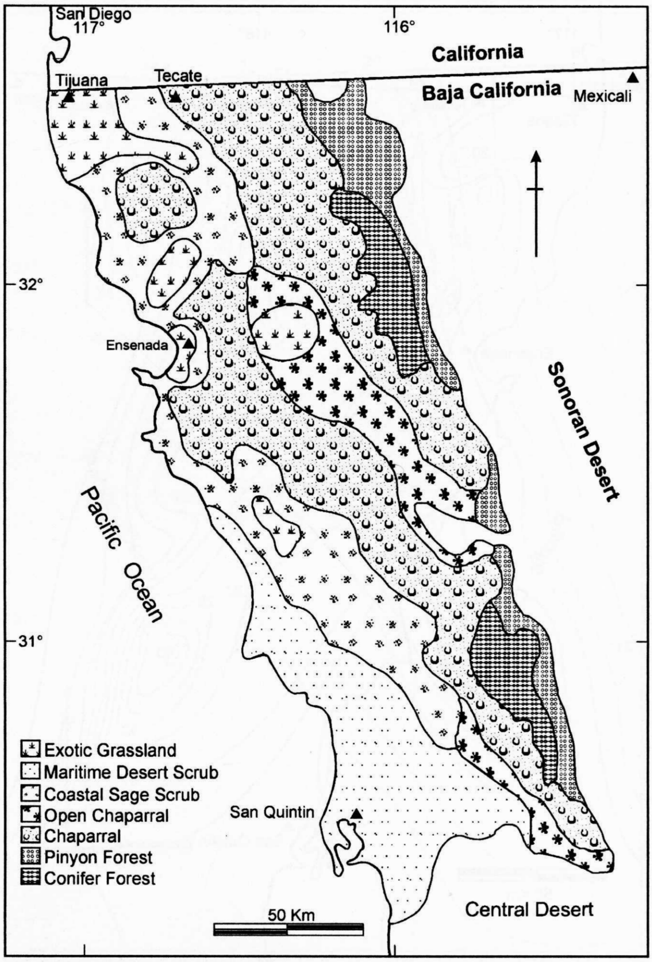

Figure 18.4. Generalized vegetation map of northwestern Baja California.

on the higher plateaus of Sierra Juárez and the west slope of Sierra San Pedro Mártir. Above 1800 m of both sierras, chamise and red shank chaparral is replaced by almost monotypic stands of peninsular manzanita (*Arctostaphylos peninsularis*).

The chaparral belt in the coastal Sierra Juárez and foothills of the Sierra San Pedro Mártir contains widely scattered closed-cone conifer forests, the dominant species having the serotinous or partially serotinous cone habit, including Tecate cypress (*Cupressus forbesii*), knobcone pine (*Pinus attenuata*), and Bishop pine (*P. muricata*). A few stands of Coulter pine (*Pinus coulteri*) occur locally in the inland Sierra Juárez and in the Sierra San Pedro Mártir, and small colonies of Cuyamaca cypress (*Cupressus arizonica* var. *arizonica*) grow in the southern Sierra Juárez. Riparian forests of western cottonwood (*Populus fremontii*) and western sycamore (*Platanus racemosa*) occur along streams, and coast live oak (*Quercus agrifolia*) grows in open woodlands along arroyos and margins of basins and on scattered north-facing slopes.

The nonserotinous Parry pinyon (*Pinus quadrifolia*) forms patchy cover in the chaparral along the crest of the interior Sierra Juárez plateau and the western Sierra San Pedro Mártir. An extensive forest of Parry pinyon occurs in association with peninsular manzanita and canyon live oak (*Quercus chrysolepis*) on the upper eastern escarpment of the Sierra San Pedro Mártir. Canyon live oak grows on steep, north-facing exposures, along canyons and on cliffs in the upper margins of the chaparral belt, including the highest mountain tops of the near-coast ranges, the peaks rising above the

Sierra Juárez plateau, and the upper mesas of the southern Sierra Juárez. Canyon live oak is widespread in the conifer forests of the Sierra San Pedro Mártir. Monotypic forests of Jeffrey pine (*Pinus jeffreyi*) are widespread on the Sierras Juárez and San Pedro Mártir from 1500 to 2000 m. Stands of this pine occur mostly on basin floors, around the margins of meadows, and along arroyos. The Sierra San Pedro Mártir above 2000 m hosts extensive mixed-conifer forests (Minnich 2001). South-facing slopes are covered with Jeffrey pine mixed with white fir (*Abies concolor*) and sugar pine (*Pinus lambertiana*). White fir and sugar pine dominate steep northern exposures, including the upper eastern escarpment, where they grow with the endemic Sierra San Pedro Mártir cypress (*Cupressus montana*).

Lodgepole pine (*Pinus contorta*) is common along meadows and arroyos of the plateau above 2400 m, often in association with quaking aspen (*Populus tremuloides*). Incense cedar (*Calocedrus decurrens*) grows near watercourses and moist north-facing slopes. Important shrubs are manzanitas (*Arctostaphylos patula*, *A. pringlei*, *A. pungens*), snow bush (*Ceanothus cordulatus*), peninsular Emory oak (*Quercus peninsularis*), and canyon live oak. The forest belt contains local wet meadows that are the focal point of cattle grazing in summer, with several meadows reaching 500 ha. Dominant genera are *Juncus* and *Carex*, and common grasses and herbs include annual bluegrass (*Poa annua*), mat muhly (*Muhlenbergia richardsonis*), buttercup (*Ranunculus cymbalaria*), willow herb (*Epilobium adenocaulon*), locoweed (*Astragalus gruinus*), evening primrose (*Oenothera californica*), water parsnip (*Berula erecta*), and thistle (*Cirsium foliosum*). Herbaceous perennials such as yarrow (*Achillea millefolium*), cinquefoil (*Potentilla wheeleri*), rattleweed (*Astragalus circumdatus*, *A. palmeri*), and *Aster occidentalis* cover drier or overgrazed meadows.

Woodlands of single-needle pinyon (*Pinus monophylla*) grow below 1500 m on the eastern escarpments of both sierras. These communities are associated with widely scattered California juniper (*Juniperus californica*) and open stands of desert chaparral, in which oaks (*Quercus cornelius-mulleri*, *Q. turbinella*, *Q. cedrosensis*), sugar bush (*Rhus ovata*), mountain mahogany (*Cercocarpus betuloides*), holly-leaf cherry (*Prunus ilicifolia*), and such leaf-succulents as Mojave yucca (*Yucca schidigera*), Parry nolina (*Nolina parryi*), and desert agave (*Agave deserti*) commonly occur.

European Land Use and Vegetation Change

The diaries of the Spanish missionaries show that the vegetation of much of northern Baja California was remarkably similar to that seen today (Minnich and Franco-Vizcaíno 1998). The diaries emphasize ethnobotanical plants (typically congeners of European species they readily recognized) and conspicuous trees such as palms. Examples of specific detail on desert species given in these manuscripts, along the explorer's routes, include the northern limits of copal (*Bursera hindsiana*) at San Felipe and coastal agave at Rosarito, as well as those of cardón and boojum tree in the southern Sierra San Pedro Mártir.

There are 2 striking examples of desert species with distributions virtually fixed in the region. With respect to copal, both *Bursera hindsiana* and *B. microphylla* grow near San Felipe. However, the stand of *B. hindsiana* located 4 km northwest of the town is apparently the same one identified in the 1906 Biological Survey (Nelson 1921) as *Elaphrium macdougalii*—a synonym for *B. hindsiana*. Nelson (1921:19) stated that this population is one of the most northerly representatives of the copals. José Joaquín Arrillaga apparently recorded the same colony on his second expedition of 1796 (Tiscareno and Robinson 1969). And in 1766, Fray Wenceslaus Linck recorded palms as far north as Agua Caliente (Burrus 1966) on the eastern escarpment of the southern Sierra San Pedro Mártir; this is the present northern limit in the range.

The diaries also indicate that the southern limits of several Mediterranean-climate species in the southern Sierra San Pedro Mártir were similar to the limits of modern ranges, including California juniper at El Salto and coast live oak at Rancho San Antonio, on the west face of the sierra, where Fray Juán Crespi made camp at a "large live oak" (*encino*) in 1769 (Bolton 1927). In particular, the diaries give a complete range of coast live oak along their routes, including sightings along the western Sierra San Pedro Mártir, in the coastal ranges from Santo Tómas to Valle Guadalupe, the west slope of the Sierra Juárez, and the transverse ranges northeast of San Vicente.

At Rancho San Antonio, Fray Junipero Serra made the remarkable observation of "two big pine trees among the rest" (Tibesar 1955:82–83). These were probably Jeffrey pines along the stream at an extraordinarily low elevation of 700 m. Jeffrey pines were

seen there by Wiggins (1944), and specimens were collected by Reid Moran in 1967 (Minnich 1987).

José Joaquín Arrillaga, who left the most detailed accounts, described in 1796 the interdigitation of pine forest in basins and chaparral on ridges of the Sierra Juárez, which can be seen today throughout the range. Arrillaga wrote a detailed account of forests and chaparral on the west slope of the range near Laguna Hanson (Tiscareno and Robinson 1969:66–67).

> [September 22]
> [from La Matanza] I started out on the trail leading west. I went up a ravine and descended to an arroyo with many pines. . . . I climbed a hill covered with an abundance of chamizo, and descended to another spacious sink, formed by several low hills. . . . I continued along this sink, which was over a league long, and which had abundant pasture. Turning to the northwest [along this arroyo], I stopped . . . by some oaks.
>
> [September 23]
> Returning to the trail I left the previous day . . . I entered a short cañada and after leaving it on the right, I went up the hillside. I crossed a mesa full of chamizo, from which I descended to a sink with sufficient pasture [and] some oaks. . . . I proceeded to skirt [southward] along the flank of the mountain, descending to a narrow arroyo, where there are . . . a few pines. The [route that followed] was [covered by] chamizo and madroño and the entire view was the same. . . . From this mesa I climbed onto another mesa, and others followed. . . . Since I left this morning our route has been toward the southwest, but then we directed ourselves toward the south until we arrived at the place they call the Arroyo of San Rafael, where all the cañadas and arroyos I crossed . . . come together. . . . [At this site] are cottonwood trees, willows, and sycamores. From La Laguna [Laguna Hanson] to this arroyo [it] is all downhill.

Arrillaga had crossed a series of ridges and canyons that feed into Arroyo San Rafael. He described several trends in the vegetation that can still be observed today: (1) forests growing in the arroyos; (2) chaparral dominated by *chamizo* and occasionally by *madroño* [*Arctostaphylos* spp.] growing on the intervening hillslopes; and (3) with decreasing altitude, the forest composition shifting from pines (*pino*, Jeffrey pine) to oaks. The higher arroyos (Cañon La Bandeja, Los Barrancos) are covered by Jeffrey pine forest, whereas lower ones (La Casa Verde, La Rosa de Castilla) contain mostly woodlands of *Quercus agrifolia* with scattered *Pinus jeffreyi*. Chaparral covering the hillslopes is dominated by *Adenostoma fasciculatum*, *Arctostaphylos peninsularis*, *A. glauca*, and *A. pungens*. Chaparral is ubiquitous on the lower slopes, as suggested by Arrillaga's remark that "the entire view was the same."

In a final example, José Longinos-Martínez gave an extensive account of the pine forests of the Sierra San Pedro Mártir in 1792 (Simpson 1938, 1961). At Vallecitos he noted that "the range is thickly covered with pines (different species from those in the lower mountains)" (Simpson 1961:28), in apparent recognition of the richer mixed-conifer forests that cover the highest plateaus. In 1888, Colonel D. K. Allen (1888a,b, 1890) examined the forest at Vallecitos for prospective timber. Allen's data confirm that tree densities, species composition, and diameters were remarkably similar to those of today, apparently due to recurrent understory fires every 50 years (Minnich et al. 2000a, Minnich 2001). Photographs taken by Ford Carpenter during an expedition in 1903 (fig. 18.5) reveal open forest similar to that described by the Biological Survey (Nelson 1921) and at present (fig. 18.6).

Today, rural Baja California is a largely unfragmented, wild landscape, with scattered patches of agriculture, reminiscent of California in the nineteenth century. The vegetation has a largely pristine character in part because the region's isolation has been responsible for a centuries-long delay in the development of agriculture and ranching after the Spanish discovery of the peninsula (see Henderson 1964). Agriculture first expanded during the dictatorship of Porfirio Díaz in 1877–1911. During this period, much of the best land, mostly grasslands in the coastal valleys and desertscrub in the Mexicali Valley and the Colorado River Delta, was cleared for crops (Henderson 1964). Dry farming of wheat and barley was developed in the coastal plains and inland valleys. The total amount of land now under cultivation is 450,000 ha, about 10% of the state north of latitude 30°.

Domestic livestock have been grazed in the coastal valleys since the Dominican missions were established in the 1770s. Cattle were driven to the mountains for summer pasture after the mission system was extended inland to Santa Catarina and the Sierra San Pedro Mártir in the 1790s (the grazing history is summarized in Henderson 1964). The mountains

Figure 18.5. View of the forest at Vallecitos in the Sierra San Pedro Mártir in 1903. (Photograph by Ford Carpenter.) Reproduced with permission from the Mandeville Special Collections Library at the University of California, San Diego.

were said to be well stocked (i.e., "carrying capacities" were reached) by 1820. Cattle numbers increased after 1850 as a result of growing markets for meat during the California Gold Rush. Americans also drove cattle from California into the mountains of Baja California. However, the number of cattle in the nineteenth century was apparently never very large. By 1857 there were 43 ranches in Baja California, with 8260 head of cattle marketed to California (Henderson 1964). The number of cattle marketed domestically is unknown, but demand was apparently low until the gold strikes of the 1870s. It was estimated that cattle numbers in the Sierra San Pedro Mártir once reached 25,000 (Allen 1890). In 1911, after the Baja California gold strikes, there were reported to be 21,000 head in the Sierra Juárez and Sierra San Pedro Mártir (Henderson 1964).

In the late nineteenth century, foreign investors began organized sheep drives, led mostly by Basque shepherds. The herds were gathered in August near Tijuana and driven to pastures as far south as the Sierra San Pedro Mártir, returning 2 months later, in October. Sheep were driven through public domain and leased land, and the wool was sold to a mill at Ensenada. As many as 30,000 sheep per year were driven along this route between 1885 and 1905 to U.S. markets. Nelson (1921) reported that large numbers of sheep were grazed on the west side of the peninsula as far south as San Quintín. Sheep grazing may have intensified beginning in 1910, when this practice was prohibited by the U.S. government within the National Forest system in southern California (Lockmann 1981; Minnich 1988). Sheep grazing declined during the middle of the twentieth century because increasing agricultural settlement in the coastal valleys discouraged land leasing to shepherds. Still, there were as many as 8000 sheep in the Sierra San Pedro Mártir in 1956 (Henderson, 1964). Sheep were prohibited from the range beginning in 1964 (Meling-Pompa 1991a,b).

During the twentieth century cattle production became an important sector of the economy of Baja California. Cattle, which numbered 32,000 head at the time of the first agricultural census in 1930 (Secretaría de la Economía Nacional 1936) grew exponentially during the twentieth century, with

Figure 18.6. View of the forest at Vallecitos in the 1990s, likely within 1 km of Ford Carpenter's 1903 site. (Photograph by R. A. Minnich.)

180,000 head reported in 1990 (INEGI 1994). It is likely, however, that much of this growth reflects the development of feedlots in the irrigated Mexicali Valley rather than a significant increase in numbers of range cattle (Henderson 1964). The number of horses and mules in the state of Baja California peaked in the 1950s at 25,000 and 8000 respectively, then declined to 10,000 and 500 as a result of mechanization (Secretaría de Economía 1951, 1956; INEGI 1994).

Feral donkeys were numerous during the nineteenth and early twentieth centuries (Henderson 1964), but their numbers plummeted as they were used to provide dried and salted burro meat, which was still available in local markets through at least the 1950s. The impact of feral donkeys has likely been replaced by that of goats, which increased from about 5000 in the 1960s to 50,000 in 1990 (Secretaría de Economía 1951, 1956; INEGI 1994). Goats are typically grazed on the open range but return to corrals every night. However, significant numbers of goats have escaped and become naturalized, and it is not known to what extent predation by coyotes and mountain lions can limit their numbers.

Goats are a potential threat because they can consume many of the coastal sage scrub plants and appear to be better adapted to them than are cattle. Genin and Badan-Dangon (1991) observed a goat herd that consumed 21 species of coastal sage scrub, of which 7 constituted 85% of the diet. These plants were deerweed (*Lotus scoparius*), California sagebrush, buckwheat (*Eriogonum fasciculatum and E. wrightii*), San Diego sunflower, lemonade berry, and bush mallow (*Malacothamnus fasciculatus*).

The impact of livestock grazing on the coastal sage scrub seems to depend on its intensity and frequency. In areas where grazing has been light to moderate, the coastal scrub can still be observed with various amounts of cover. The arrival of Old World exotic annual grasses and forb species may have made coastal sage scrub more attractive for livestock because some invasive species can produce more forage than the indigenous wildflowers, described in the region during the Spanish explora-

tions and by botanists during the late nineteenth century (Minnich and Franco-Vizcaíno 1998).

With increases in carrying capacity, livestock may further augment browse pressure and physical removal of canopy. Currently, the coastal and inland basins show the unmistakable effects of grazing, including contoured livestock trails, thinning of the herbaceous layer, pruned shrubs, and fecal deposits. Browse preferences may result in selective removal of some shrub species (Genin and Badan-Dangon 1991). Although *Eriogonum fasciculatum* is preferred by cattle for fodder, this shrub apparently gains a selective edge over other coastal shrub species due to its ability to colonize disturbed ground. No historical baseline data exist to evaluate the species composition and structure of coastal sage scrub before grazing and the arrival of exotic annuals.

Cattle grazing is still practiced in seasonal transhumance in both the Sierras Juárez and San Pedro Mártir, and the same families have been in control of the highlands since the early nineteenth century (Meling-Pompa 1991a,b). During the rainy season, cattle graze on annual herbaceous cover in coastal sage scrub and in exotic grasslands, as well as on crop stubble in the agricultural zones. Once the annual grasslands have cured (i.e., died and dried), cattle are driven to the mountain meadows during May and June.

The mountain meadows are the primary source of feed, and estimated cattle-carrying capacities range from 2 to 15 ha per animal unit per year (Henderson 1964). Estimates of carrying capacity in chaparral, coast live oak, pinyon and Jeffrey pine forests at 4 *ejidos* in the northern Sierra Juárez vary from 20 to 50 ha per animal unit per year (summary in Minnich and Franco-Vizcaíno 1998). Estimated carrying capacities are lowest in chaparral because most shrub species are unpalatable to cattle. Along the international boundary east of Tecate, the carrying capacity is so low that livestock on both sides of the border depend almost entirely on irrigated pasture and/or supplemental feeding (Minnich and Bahre 1995). Estimated carrying capacities in pinyon forest range from 30 to 34 ha per animal unit per year.

Open range grazing has apparently had significant effects on the vegetation of the mountain meadows. Fragmentary descriptions in 1887–1889 indicate that meadows in both sierras were in excellent condition (Minnich and Franco-Vizcaíno 1998). The most notable impact of livestock grazing seems to have been the selection for species with low, prostrate growth forms such as *Achillea millefolium*, *Aster occidentalis*, *Potentilla wheeleri*, and *Trifolium wigginsii*. Today these plants typically reach heights of 3–5 cm during years of normal precipitation and reach 20–30 cm during El Niño years.

Cattle exclosure studies show that grazing by livestock reduces biomass in the meadows (Minnich et al. 1997), but results on consequent changes in species composition are inconclusive. During drought in 1989–1990, meadow biomass in exclosures was 50% greater than the unfenced controls. During years of normal or above-normal precipitation (e.g., 1991, 1992, 1993), meadow productivity increased by an order of magnitude, but there was little difference between exclosure and control biomass, perhaps because high productivity rates reduced cattle pressure.

In a similar finding, sapling counts and cattle exclosure studies in mixed-conifer forest (M. G. Barbour, pers. comm.) suggest that cattle grazing has no measurable effect on herbaceous and shrub cover, nor on conifer recruitment, in the forests. Although evidences of cattle such as fecal deposits are seen in most forests, animals spend most of their time in meadows because forests contain limited herbaceous cover. Most shrub species in the chaparral and mixed-conifer forest are unpalatable to livestock (Minnich and Bahre 1995).

Studies of pollen preserved in soils and sediments are needed to evaluate grazing impacts over the past 2 centuries. Four non-native species have been reported in the Sierra San Pedro Mártir, including filaree, cheat grass (*Bromus tectorum*), common dandelion (*Taraxacum officinale*), and *Koeleria macrantha* (Sosa-Ramírez and Franco-Vizcaíno 2001), but their distribution is limited and their abundance is low.

Outside the now extensive urban areas in northwestern Baja California, the most significant vegetation change in Baja California has been the invasion of Eurasian grasses and forbs across the coastal and inland valleys north of San Quintín. The timing of invasions may have been similar to that in California (Hendry 1931). In 1769, the Franciscan missionaries brought the first exotics that spread extensively in Baja California. Burr clover (*Medicago hispida*) was found at the Mission San Fernando Velicatá by 1769. Black mustard and filaree were recorded in mission bricks dating to

1780 at Santo Domingo and San Vicente. Duhaut-Cilly recorded that *B. nigra* became a terrible scourge in the plains of Los Angeles by 1820s (Carter 1929). It was probably widespread in Baja California by that time. In the late nineteenth century, Orcutt (1886a) saw houses made of mustard stalks at San Vicente, likely the alien black mustard. Other "Franciscan exotics" were abundant by that time. Orcutt (1886b: 41) states that the pasture at San Quintin "was exactly like that of Alta California: alfilleria [*Erodium cicutarium*], alfalfa [*Trifolium* spp. ?], burr [*Medicago polymorpha*] and red clovers [*Trifolium* spp.] make [up] the greater part of the forage plants." However, the alfilleria was "too scattered to be good feed" (Orcutt 1886b: 41). Wild oat (*Avena fatua*) was not recorded in mission bricks and may have been introduced some years after the construction of the missions.

Accounts from Alta California suggest that wild oat was widespread before the gold rush (e.g., Frémont 1848). In 1855, the U.S.–Mexico boundary survey reported that in coastal valleys of southern California,

> the wild oat *Avena fatua* is so extensively naturalized, that it gives every fertile tract the appearance of a cultivated field. The wide plains that border the sea in the neighborhood of Los Angeles are covered with the richest pasturage. The *Erodium cicutarium*, with several species of wild clover (*Trifolium* and *Medicago*) are mingled with a variety of other herbage, and thus serve to give a meadow-like aspect to this teeming land. (Parry 1859:18).

In 1861, José Matías Moreno wrote that in the pastures along the Pacific coast of northern Baja California, "the most abundant [species] are oats, alfilerillo, trifolium and grass" (Piñera-Ramírez and Martínez-Zepeda 1984:13). William M. Gabb, who traversed the entire Baja California peninsula in 1866–1867 stated that in Valle Guadalupe "the grass in the uncultivated parts . . . was unsurpassed by anything we saw on the whole journey" (Orcutt 1886b:38). Given the widespread extent of *Avena fatua* in California by that time, Gabb was likely describing oat fields in this valley.

Accounts by Davidson (1891), Abrams (1904), and Parish (1920) indicate that non-native brome grasses (*Bromus rubens*, *B. diandrus*) began increasing in coastal California only by 1900. The botanist Samuel Parish reported that bromes were common in southern California by 1920. The bromes, as well as slender wild oat and short-podded mustard, began to dominate grasslands and coastal sage scrub by the end of the century (Minnich and Dezzani 1998). Bromes were not described by Orcutt or the Biological Survey and thus must have expanded through the northern peninsula during the twentieth century.

Exotic annual grassland now covers areas described as pasture by early Spanish explorers. The ambiguities of late-eighteenth-century Spanish diaries lend little insight to pre-European herbaceous vegetation. The frequently used term *pasto* does not necessarily mean "grassland," as has been conventionally translated (Bolton 1927, 1930; Brown 2001), but rather "pasture" with an uncertain amount of grasses, if any (Minnich and Franco-Vizcaíno 1998). The "*Stipa*" bunch grass model, summarized in Heady (1988), is from Clements' (1920) "plant indicator" model of potential climax communities, but it is not based on historical evidence (Hamilton 1997).

Spanish diary entries in California during the spring months consistently describe fields of flowers, not bunch grasslands. The diary of Crespi, the only expedition to have crossed northern Baja California during the spring, did not describe flower fields in Baja California. Perhaps 1769 was a dry year. However, Orcutt (1886a) describes wildflowers at several locations such as Tijuana, Ensenada, San Telmo, and east of El Rosario. For example, he described the bay of Ensenada as being covered

> by magnificent fields of gold California poppy [*Eschscholzia californica*], *phacelias*, *layia elegans* [*Layia* sp.], *orthocarpus*, *baerias* [*Lasthenia* spp.], larkspurs [*Delphinium* spp.], *platystemon* and other delicate annuals and perennials which lent an added charm to the beauty of land and sea that was spread out before us on every hand. And thus for mile after mile we alternatively contemplate the rich garden of flowers and the beautiful scenery. (p. 54)

Invasive exotic grasses, especially bromes, have increased the flammability of herbaceous ecosystems. In the Central Valley and interior valleys of California, areas covered by forbs were described by early travelers as being barren in summer (Wester 1981). The journals of Crespi, Serra, and Arrillaga, which cover expeditions in late spring and early summer, indicate that barrenness was also characteristic of the valleys of Baja California in the dry

season. Apparently the indigenous herbacous cover left little remnant fuels when they cured. Hence, herbaceous biomass and fire hazard may have increased with the invasion of exotic annuals, but fuel build up may have been reversed by livestock grazing. Grasslands only periodically support extensive fires, usually after wet years when inflammable biomass exceeds grazing pressure (Minnich 1983). Perhaps the greatest loss of biodiversity in Baja California has been the decline or extirpation of annual wildflowers due to invasions by exotic annuals. Spring wildflowers have become ever more infrequent along the Pacific coast in recent decades (E. Franco-Vizcaíno, pers. obs.).

Although most of the population of northern Baja California was rural during the nineteenth century, the impact of woodcutting for domestic fuel was probably local and of little regional significance. The introduction of natural gas and propane for heating and cooking predates the population explosion that occurred after World War II in the border cities. Gold discoveries between 1873 and 1889 resulted in the establishment of several boomtowns of 500–1650 people in the Sierras Juárez and San Pedro Mártir (Chaput et al. 1992). Because nearly all of the gold discoveries were placers, the demands for fuelwood for such processes as smelting, running stamps, pumps, and ore crushers were limited, and, moreover, the best ores played out within a few years of discovery (Chaput et al. 1992).

Cattle ranchers have used Jeffrey pine, California juniper, and red-shank chamise, as well as other chaparral species, for fence posts and corral construction since the early nineteenth century, but the impact from the construction and maintenance of such infrastructure is unknown. Wood utilization may have been light because most of the mountains have remained open range until recently. Most fencing was built to subdivide prime meadows and ranchsteads. Jeffrey pine has been used for construction of primitive summer shelters.

Low human population densities and the inaccessibility of the pine forests prevented significant removal of timber during the past 2 centuries. During the Dominican mission period, Arrillaga recorded in his journal that pine trees on the west slope of the central Sierra Juárez near San Salvador were cut for Misión Santo Tomás, but that likely involved only a few trees. Coulter pine forests were part of the territory under the jurisdiction of Misión San Miguel, but it is unclear whether that remote stand was ever exploited. Utilization of closed-cone conifer forests was probably limited because most forests have been made inaccessible by impenetrable chaparral with which it normally grows. The trees also make poor fuelwood because of their small size.

Pine forests were logged during the mining strikes at Japá (1873–1874) and El Alamo (1889–1890). The International Colonization Company built a road from El Alamo to the forests at La Tableta (25 km south of Laguna Hanson), but the mill probably both lasted only a few years and had little impact on the forest there. The Ejido Sierra Juárez established a gasoline sawmill at Arroyo del Sauz, 5 km south of Laguna Hanson, in the 1930s and ran a limited logging operation in Jeffrey pine forests in the central part of the range. A federal census in 1940 states that 250 ha of a total of 23,000 ha of forest had been exploited (Minnich and Franco-Vizcaíno 1998). This *ejido* has not been actively logging since the 1970s, and we could not find any information on how much timber was removed between 1940 and 1970. The impact of the *ejido* logging operation on forest structure may have been negligible. Only selective logging of old-growth trees was practiced within a radius of 20 km of the Laguna Hanson (Haiman 1973), and understory fires (maps in Minnich and Chou 1997) have maintained open, mature stands in these cutover areas. The Ejido Bramadero obtained a permit in 1996 to log trees infected with dwarf mistletoe or infested with bark beetles in an 1800-ha parcel in *ejido* lands in the northwestern Sierra San Pedro Mártir outside the National Park, but logging operations were delayed several years and apparently stopped by the authorities in spring 2001 after only a few truckloads of logs had been exported to the United States. The continuation of logging remains under litigation.

Uncontrolled Fire and Dynamics of Baja California's Ecosystems

In Baja California's Mediterranean climate, wildland fire is strongly integrated into the ecological function, structure, and distribution of many plant communities. Fire regime properties (fire intervals, intensity, severity, removal of canopy) are outcomes of climate and the characteristics of the vegetation. Climate affects plant growth, productivity, and rates of fuel build up, and vegetation structure affects fire behavior and maintenance of the canopy. These factors exert selective forces on the distribution of fire-prone ecosystems (see Allen et al. 1991; Veblen

et al. 1991; Christensen 1993; Barton 1994; Minnich 2001).

In Baja California's chaparral and mixed-conifer forests, fires result in fine-grained and self-organized patch mosaics of stands that range mostly from 500 to 5000 ha. Because a time lag exists between fuel accumulation and burning, the inflammability of communities increases with time. Fires preferentially burn old stands (> 40–50 years), whereas younger stands constrain the progress of burns (Minnich and Chou 1997; Minnich 2001). In both chaparral and mixed-conifer forests, fire occurs about twice per century. In Baja California, fires seem to occur at random in normal weather, and this results in slow spreading of flame lines and low fire intensities. In Alta California, the efficient suppression of small fires selects for extensive burning by relatively few, very intense fires. Because fire occurrence in Alta California is nonrandom and tends to coincide with drier, windier weather, fires have attained sizes as large as 60,000 ha. This enlargement in fire size in Alta California is also related to the homogenization of the patch mosaic (Minnich and Chou 1997).

Studies of post-fire succession in Alta California show that species composition and stand structure take on the characteristics of the surrounding mature communities within 20–40 years. Dominant species resprout or establish from soil seed banks within a few years after fire, and successions respond to variable fire intervals (summaries in Hanes 1988; Keeley 2000). Chaparral was degraded only when fire intervals were < 10 years because seeding species were burned before reaching reproductive maturity, and sprouters experienced increased mortality form carbohydrate depletion. Short fire sequences were encouraged by invasive Mediterranean annual grasses. Nutrient enrichment in chaparral after wildland fire is also less pronounced and more transitory in Baja California than is typically reported for burned shrublands in Alta California (Franco-Vizcaíno and Sosa-Ramírez 1997).

A chronosequence study along the U.S.–Mexico boundary that compared successional states of chaparral patches in coarse-grained mosaics on the U.S side with fine-grained mosaics on the Mexican side found that successional sequences were similar in both countries (Minnich and Bahre 1995). The authors concluded that the responses of chaparral species were independent of fire size due to sprouting and seedbank strategies. No dominant species required long-range seed dispersal to recolonize burns.

In contrast, grassland and coastal sage scrub have limited buildup of fuel and relatively high decomposition rates in winter; this results in more variable time intervals between fires than in chaparral (Minnich 1998). Stands have high levels of dead biomass during the dry season due to the drought dormancy of subshrubs and the curing of annuals. Decomposition rates are relatively high during winter because fine fuels have low lignin content. Thus, the levels of standing fuel primarily reflect annual productivity. The rapid accumulation of fuel makes entire landscapes inflammable, regardless of previous fire history. This results in a spatially random turnover of patches; that is, fires spread independently of patch structure. Consequently, fires in annual grasslands and coastal sage scrub in Baja California can grow as large as 10,000 ha, especially after a season of high rainfall and near the international boundary, where productivity is higher than farther south (Minnich 1983).

Conservation Issues

Protected by historical isolation, much of rural Baja California remains a showcase of unmanaged biota functioning with relatively little human exploitation or interference, in sharp contrast to wildlands in Alta California. Isolation continued into the late twentieth century, as urban and agricultural growth concentrated in the rich Mexicali Valley and the border cities. However, the opening of the transpeninsular highway in 1973 contributed to rapid economic growth along the northern Pacific coast. The road to the National Astronomical Observatory opened the Sierra San Pedro Mártir to the outside world in the early 1970s. North of the 30th parallel, only two National Parks, Constitución de 1857 at Laguna Hanson and San Pedro Mártir, have Natural Protected Area status. Although the national parks were established by presidential decree in 1947, they have been actively administered (jointly by the state and federal governments) only since 1997. A new Natural Protected Area, Valle de los Cirios, was established in 2001 and covers nearly all lands from the 30th parallel to the southern boundary at the 28th parallel, including Isla Cedros.

The establishment of Natural Protected Areas (the Spanish acronym is ANP) is the beginning of a sustainable system for the protection of Baja California's extraordinary ecosystems, which are unique in Mexico. But because the current ANPs already

represent such a large proportion of the state, it is unlikely that other areas deserving protection will be included in government plans in the near future. Although nongovernmental conservation organizations (NGOs) are weakly developed in Baja California compared to those in the United States, several NGOs including Pronatura, Pro-Esteros, and Terra Peninsular are currently working to conserve lands that do not enjoy official protection.

A critical priority for conservation is the coastal sage scrub in its natural setting adjacent to beaches. North of Ensenada, only a few kilometers of coastline at Playa Azúl still have relatively undisturbed coastal sage scrub. This area is currently threatened by the proposed development of one or more liquefied natural gas terminals that would off-load gas from ships to supply natural gas and electrical energy to southern California. Efforts are underway by NGOs to conserve this remaining patch of coastal sage scrub, possibly through a land swap that would locate the gas terminals at already developed sites. South of Ensenada, another important region for conservation of coastal sage scrub is the roadless area south of the Punta Banda peninsula.

A large portion of the maritime desertscrub adjacent to the ocean has been extirpated by agricultural and tourism development along the San Quintín coastal plain. Local inhabitants and NGOs have been working to protect San Quintín Bay and its spectacular volcanoes, covered with maritime desertscrub, from the development of a major tourist complex that would include a marina, hotel, golf course, and an airport. Other areas important for conservation of maritime desertscrub are south of Eréndira and the dune complex south of San Quintín.

Baja California's chaparral and conifer forests are still well protected by their resilience and isolation and may serve as a showcase for research in fire ecology for similar ecosystems throughout the southwestern United States and northwestern Mexico. In the long run, maintaining the current unmanaged fire regime will likely be more economical and less threatening to life and property. Establishment of a biosphere reserve in the Sierra San Pedro Mártir has been proposed as a way of involving the local population in the conservation and sustainable development of the chaparral and mixed-conifer ecosystems (Minnich et al. 1997). A biosphere reserve in the Sierras Juárez and San Pedro Mártir may be a more favorable model for resource management because it implies a more democratic and transparent decision-making process than that afforded by national parks and other ANPs, which are operated by a centralized authority.

The reintroduction of the endangered California condor (*Gymnogyps californianus*) in the Sierra San Pedro Mártir was an idea conceived independently and at about the same time by us and by Amadeo M. Rea (G. Ceballos, pers. comm.). It was proposed by Minnich et al. (1997) as a way of rallying regional, national, and international support for a biosphere reserve. The reintroduction effectively began with the release in October 2002 of the first California condors, in an area adjacent to the Sierra San Pedro Mártir National Park. The condor recovery team believes that the species has an excellent chance for successful naturalization in the Sierras Juárez and San Pedro Mártir (M. Wallace, pers. comm.). The eastern escarpment contains abundant cliff faces and ledges favorable to their roosting and nesting, and updrafts associated with the high relief are also favorable for soaring. Chaparral and other plant ecosystems have a diverse patch structure that allows location of carrion food sources as well as landing and takeoff. The reintroduction of the California condor to the sierras may serve as a management centerpiece for the national parks or the establishment of a biosphere reserve because this effort will bring international attention and require the integration of sustainable management of the region's natural resources, now under threat from accelerating development.

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